Semiconductor Properties of the DLC Thin Films Doped with Nitrogen

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Obtained ta–C:H:N films have been produced by the plasma enhanced chemical vapor deposition method from multi-component gas mixture of $Ar:N_2:C_7H_8$ composition. Plasma source parameters have a great impact on the structure of produced films as well as on the electro-physical and optical characteristics of the films. Properties of the obtained films were studied as depended upon the following parameters: acceleration voltage: U_{ac}=(1.5–3) kV; ion current density: J=(0.5–3.5) mA cm^{-2}; ion kinetic energy: E_k=(20–150) eV, as well as on the ratio of gas mixture and pressure in the vacuum system [1]. Three-axis rotation system in the plasma region allowed to produce homogenous films with above-given characteristics on the large-area substrates of various materials: crystalline Si and Al_2O_3, amorphous quartz, silicate and organic glass [2]. Hydrogenated tetrahedral amorphous carbon (ta-C:H:N) DLC thin films were deposited on the surface of these materials by the including of nitrogen into the gas mixture being supplied to direct current ion source.

The optimized average thickness of the produced films is ~200 nm measured by the ellipsometric (at 630 nm wavelength) and by the interference methods. The obtained films are transparent in the visible light (360–1200 nm) spectra. Optical band gap width and coefficient of absorption have been determined by the Tout’s method based on the transmission spectra data.

As the investigations showed, the higher the concentration of the C_7H_8 in the gas mixture, the lesser the optical band gap width and the slope of the Tout’s curve 1.0–3.5 eV.

DLC films were deposited on the surface of the crystalline n-type Si to determine the temperature dependence of electric parameters. Ni electrodes were deposited on the DLC film for carrying out both electrical and photoelectrical measurements. Ohm contacts to the Si substrate were formed with the help of arc welding of metallic In [3].

Ni/DLC/n-Si/Ni system was developed and investigated. Current-Voltage, Capacitance–Voltage dependences and Q-DLTS spectra were also determined.

It was shown that the obtained films have cluster structure [4].

The I-V characteristics of Ni/DLC/Si/Ni structure with DLC layer doped by nitrogen in different concentrations are shown on Fig.1. The obtained films are enough stable relative chemical, thermal and radiation influences, possesses by good microhardness and adhesion with various substrates. These films are successfully used in electronics, optics, as well in solar energy photovoltaic converters as protective and antireflective coatings [5].

Three samples marked as 1,2 and 3 shows that their electro physical parameters are essentially different. The conductivity determined with the help of the voltage-current characteristics analysis is changed in 9 times for different samples as it follows from Fig.1.

The temperature dependence of specific conductivity (σ) justifies the semiconductor properties of obtained DLC films Fig.2. Increasing in temperature in two times leads to σ increasing in the 5 orders. Analysis of I-V characteristics temperature dependencies evidenced hopping mechanism of charge transfer across the localized states. The sample #2 with the more density of defects possesses high conductivity. The samples 1 and 3 have low density of states and characterized by better insulate properties. The investigation of photovoltage kinetics of all samples shows that band bending in Si substrate for sample 1 is more comparing with others. The activation energies and cross-sections of defect centrums are determined.

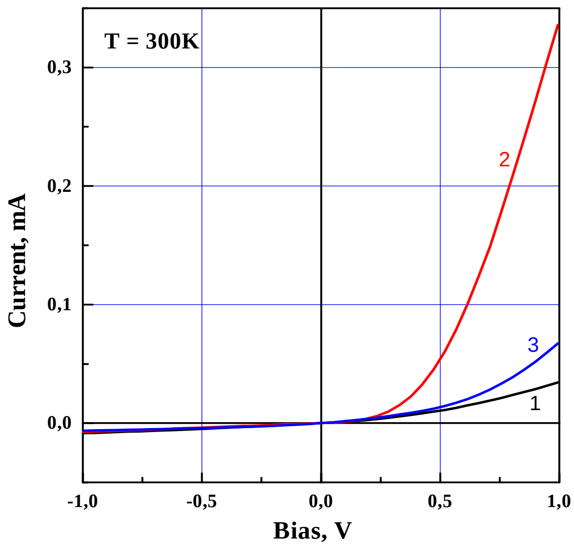

Fig.1. I-V characteristics of thesamples 1,2 and 3.

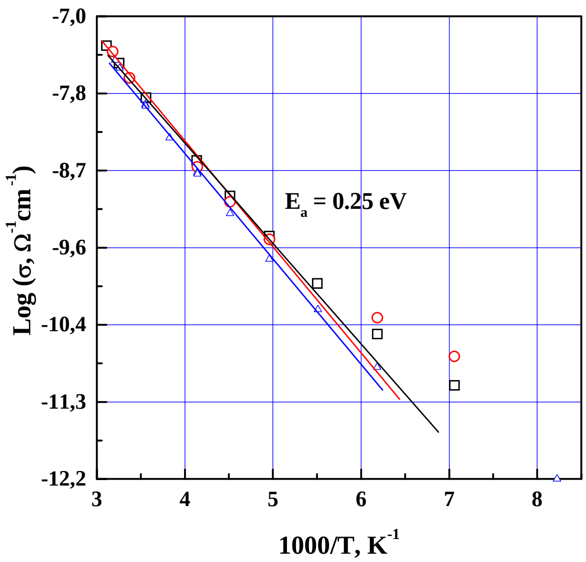

Fig.2 Arrhenius plots of the samples 1,2,3 (from I-V). E_a - the activation energy of conductivity.

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